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Exploration Systems Mission Directorate
Robotic Lunar Exploration Program
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LUNAR RECONNAISSANCE ORBITER (LRO) REQUIREMENTS

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NOVEMBER 30, 2005

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ACKNOWLEDGEMENTS

The Lunar Reconnaissance Orbiter (LRO) is the first mission in support of fulfilling on the Nation's Vision for Space Exploration. Thirty years ago, previous exploration missions to the Moon captured our imagination. The LRO mission begins where we left off by exploring and characterizing the Moon's polar regions and by improving our knowledge of the lunar surface globally. This new exploration will enable safe and sustainable human and robotic exploration of the Moon for decades to come and will also fundamentally improve our understanding of the origin and evolution of our solar system.

To expedite the start of the mission, a group of experts led by Dr. Jim Garvin provided the necessary expertise and insight to help define the LRO mission objectives. The group was called the Objectives, Requirements and Definition Team (ORDT), and met in March 2004. Their findings were the basis for the LRO Instrument Announcement of Opportunity (AO). We appreciate their time and acknowledge their valuable contribution to this important effort.

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Once the ORDT was complete, Jennifer H. Trosper (NASA JPL) led the effort to develop the Robotic Lunar Exploration Program (RLEP) requirements and the original draft of this document.

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1.0 INTRODUCTION AND SCOPE

This document identifies the Mission Requirements (Level 1) for the Lunar Reconnaissance Orbiter Project. It serves as the basis for assessments conducted by NASA Headquarters and provides the baseline for the determination of mission success during the operational phase. This document contains all the Program unique requirements on the Lunar Reconnaissance Orbiter mission and the traceability from those requirements. Changes to requirements contained in this document require approval by the Robotic Lunar Exploration Program (RLEP) Office and the Exploration Systems Mission Directorate (ESMD), NASA Headquarters.

In January 2004, the President of the United States announced a new plan to advance the Nation's scientific, security, and economic interests through a robust space exploration program that integrates human and robotic exploration activities. This decision was documented by the "President's Space Exploration Policy Directive (NPSD31)(Goal and Objectives)," and "A Renewed Spirit of Discovery - The President's Vision for U.S. Space Exploration (January 2004)." The specific actions required to carry out this new exploration program have been further elaborated on in the NASA response document, "The Vision for Space Exploration," dated February 2004. The Robotic Lunar Exploration Program was then established to implement the robotic precursor missions to fulfill on the Lunar Program Requirements. The Lunar Reconnaissance Orbiter (LRO) is the first mission within the Program.

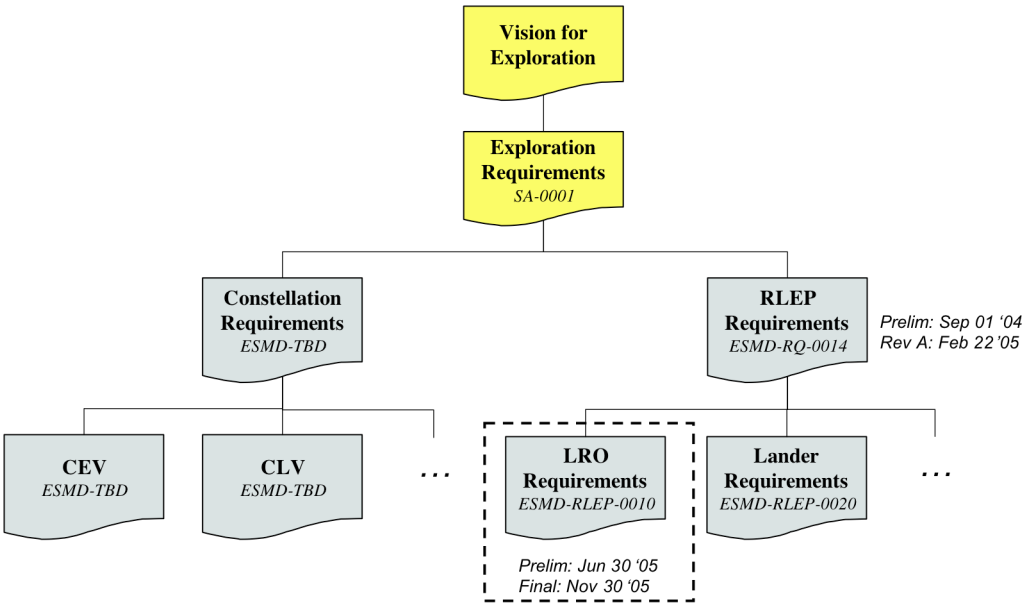

Figure 1-1 ESMD Requirement Flow-Down Diagram

A joint Enterprise working group at NASA Headquarters subsequently established the Level 0 Exploration Requirements for the National Aeronautics and Space Administration effective May 4, 2004. The relevant lunar exploration requirements were flowed-down into the Robotic Lunar Exploration Program and Lunar Reconnaissance Orbiter requirements documents as shown in Figure 1. As a result, the Lunar Reconnaissance Orbiter Project objectives are to develop an understanding of the Moon in support of human exploration, understand the current state and evolution of volatiles and other resources in context and to characterize the biological effects of the lunar radiation environment.

Due to the timely launch of the LRO mission in 2008, the LRO Project was initiated before its parent requirements were completely understood, defined and allocated. Consequently, a complete flow down from a fully developed set of exploration requirements to LRO was not possible. The LRO measurement priorities were advised by lunar exploration community and instruments selected by NASA Headquarters. As such, most of the measurement requirements in this document reflect the capabilities of the selected instruments in response to the AO, complemented by our best judgment that these capabilities are likely to meet or exceed the needs of the overall exploration program. Once the exploration requirements have been fully developed, these requirements will need to be reviewed and possibly revised. However, it is our belief that the process we substituted is highly likely to ensure that the LRO mission is valued added to exploration.

1.1 PROJECT ORGANIZATION AND MANAGEMENT

The Lunar Reconnaissance Orbiter project is organized and managed within the Robotic Lunar Exploration Program. Technical program management of LRO will be conducted within the structures, policies, and procedures defined for the implementation of all projects within the Robotic Lunar Exploration Program. These structures, policies, and procedures are defined within the RLEP Program Plan and are included herein by reference. The RLEP Manager has the end-to-end responsibility for program implementation, and programmatically reports to the NASA ESMD Associate Administrator at Headquarters. Programmatically, the LRO Project manager is responsible to the Robotic Lunar Exploration Program Manager.

1.2 PROJECT ACQUISITION STRATEGY

The LRO Project will provide the orbiter, Ground Systems, and Ground Network. The NASA Kennedy Space Center (KSC) will competitively procure and deliver launch services and spacecraft integration support for the LRO. The Project will support and implement within its allocated resources NASA's measurement investigations selected through the Announcement of Opportunity (AO) process and other investigations as directed by NASA.

Six institutional partners, under contract to the LRO project at GSFC, are responsible for delivery of the six scientific instruments to be flown on the LRO:

Goddard Space Flight Center - Lunar Orbiter Laser Altimeter (LOLA)

Northwestern University - Lunar Reconnaissance Orbiter Camera (LROC)

Institute for Space Research - Lunar Exploration Neutron Detector (LEND)

University of California, Los Angeles - Diviner Lunar Radiometer Experiment (DLRE)

Southwest Research Institute - Lyman-Alpha Mapping Project (LAMP)

Boston University - Cosmic Ray Telescope for the Effects of Radiation (CRaTER)

2.0 APPLICABLE DOCUMENTS

Document No.	Document Title
SA-0001	Level 0 Exploration Requirements for the National Aeronautics and Space Administration, Baseline Version, May 4, 2004
N/A	Objectives and Requirements Definition Team (ORDT) for the Lunar Reconnaissance Orbiter (LRO)
NPSD31	President's Space Exploration Policy Directive (Goal and Objectives)
ESMD-RQ-0014	Robotic Lunar Exploration Program (RLEP) Requirements
N/A	Report of the President's Commission on Implementation of the United States Exploration Policy, A Journey to Inspire, Innovate, and Discover. June 2004
N/A	National Aeronautics and Space Administration, The Vision for Space Exploration. February 2004.
NNH04ZSS003O	Announcement of Opportunity, Lunar Reconnaissance Orbiter (LRO) Measurement Investigations
N/A	Lunar Reconnaissance Orbiter (LRO) Payload Proposal Information Package (PIP)

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3.0 REQUIREMENTS

3.1 LRO LEVEL 1 REQUIREMENTS

The NASA established LRO Objectives/Requirements Definition Team (ORDT) defined specific LRO measurement objectives based on historical Apollo data and approaches, anticipated needs for future human exploration and an assessment of our current state of knowledge of the Moon. Those findings were then reviewed by ESMD and a set of initial requirements were subsequently recommended for approval by the cognizant Enterprise Associate Administrators (AA). The AAs for Exploration Systems, Space Science, Biological and Physical research, and Space Flight jointly approved them on May 24, 2004. Subsequent to the initial approval, the LRO Instrument AO was released and instruments were competitively selected. The requirements in the AO and the Program requirements in ESMD-RQ-0014 were then used as the basis of this document. Further reviews were then held leading to the approval of this document. The requirements development process is illustrated in Figure 3-1.

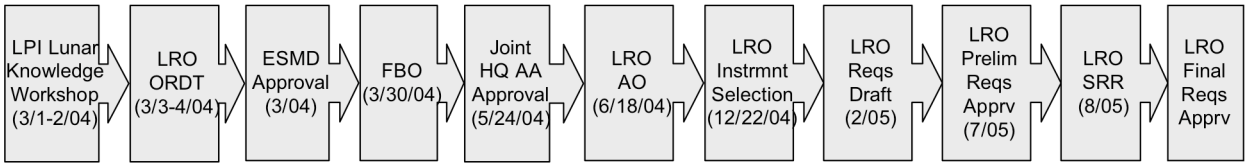

Figure 3-1. LRO Requirement Definition Flow Diagram

The LRO Level 1 requirements are divided into two sections: Measurement Requirements and Project Requirements.

3.1.1 Measurement Requirements

NASA has established the following investigation measurement requirements for LRO based on RLEP Requirements and the LRO AO and refined further from the mission instrument selections and Project trade studies. All spatial resolution requirements are based on a 50km nominal orbital altitude. The Moon's polar regions are defined as being within 5 degrees of the pole, unless specified otherwise.

RLEP-LRO-M10 The LRO shall characterize the deep space radiation environment at energies in excess of 10 MeV in lunar orbit, including neutron albedo.

> *Rationale* : LRO should characterize the global lunar radiation environment in order to assess the biological impacts on people exploring the moon and to develop mitigation strategies.

RLEP-LRO-M20 The LRO shall measure the deposition of deep space radiation on human equivalent tissue while in the lunar orbit environment.

> *Rationale*: The radiation environment needs to be characterized in order to assess its biological impacts and potential mitigation approaches, including shielding capabilities of materials and validation of other deep space radiation mitigation strategies.

RLEP-LRO-M30 The LRO shall measure lunar terrain altitude to a resolution of 10cm and an accuracy of 1m for an average grid density of approximately 0.001 degrees latitude by 0.04 degrees longitude.

Rationale : LRO should determine the global geodetic grid for the Moon in three dimensions with high spatial resolution to facilitate landing site selection, safety analyses and to enable surface navigation. This requirement was created based on the selected instrument performance. It may be reviewed once a more structured allocation of exploration requirements to RLEP has been completed.

RLEP-LRO-M40 The LRO shall determine the horizontal position of altitude measurements to an accuracy of 100m.

Rationale : LRO should determine the global geodetic grid for the Moon with high spatial accuracy to improve lunar navigation capabilities which will facilitate safe landing, enable effective robotic and crewed landing system designs (especially efficient fuel usage) and to enable surface navigation. This requirement reflects our assessment of the likely capability of the LRO based on the selected instruments. Based on subjective expert judgment, we believe these requirements will meet or exceed the needs of the broader exploration program once they are explicitly defined.

RLEP-LRO-M50 The LRO shall obtain temperature mapping from 40 - 300K in the Moon’s polar regions to better than 500m spatial resolution and 5K precision for a full diurnal cycle.

Rationale : LRO should assess the thermal environment of the lunar surface in order to support design of surface systems for exploration, and to support resource location in the Moon's polar regions. This requirement reflects our assessment of the likely capability of the LRO based on the selected instruments. Based on subjective expert judgment, we believe these requirements will meet or exceed the needs of the broader exploration program once they are explicitly defined.

RLEP-LRO-M60 The LRO shall obtain landform-scale imaging of lunar surfaces in permanently shadowed regions at better than 100m spatial resolution.

Rationale : LRO should assess the lunar surface landforms in order to support identification of potential cold-traps and to support registration of higher resolution images and data products. This requirement reflects our assessment of the likely capability of the LRO based on the selected instruments. Based on subjective expert judgment, we believe these requirements will meet or exceed the needs of the broader exploration program once they are explicitly defined.

RLEP-LRO-M70 The LRO shall identify putative deposits of water-ice in the Moon’s polar cold traps at a spatial resolution of better than 500m on the surface and 10km subsurface (up to 2m deep).

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Rationale : LRO should assess the resources in the Moon's polar regions including characterization of permanently shadowed regions and evaluation of any water ice deposits to enable sustainable and affordable exploration. This requirement reflects our assessment of the likely capability of the LRO based on the selected instruments. Based on subjective expert judgment, we believe these requirements will meet or exceed the needs of the broader exploration program once they are explicitly defined.

RLEP-LRO-M80 The LRO shall assess meter-scale features of the lunar surface to enable safety analysis for potential lunar landing sites over targeted areas of 100km^2.

Rationale : LRO should assess the surface of the Moon's polar regions at high resolution to support effective design of crewed landing systems and increase the probability of safe landings by robotic and crewed systems.

RLEP-LRO-M90 The LRO shall characterize the Moon's polar region illumination environment to a 100m spatial resolution and 5 Earth hour average temporal resolution.

Rationale : LRO should assess the Moon's polar region illumination environment to support landing site evaluation, location of permanently shadowed regions and possible regions of constant solar illumination. This requirement reflects our assessment of the likely capability of the LRO based on the selected instruments. Based on subjective expert judgment, we believe these requirements will meet or exceed the needs of the broader exploration program once they are explicitly defined.

RLEP-LRO-M100 The LRO shall characterize lunar mineralogy by mapping the thermal properties of regolith and characterizing UV, visible, and infrared spectral differences and variations at km scales globally.

Rationale : LRO should obtain high spatial resolution assessments of global lunar mineral resources to enable sustainable and affordable exploration.

RLEP-LRO-M110 The LRO shall perform hydrogen mapping of the Moon's surface with a sensitivity of 100 ppm or better, a SNR of 3, and 10 km resolution in the polar regions.

Rationale : LRO should obtain (10km spot) spatial resolution assessments of global lunar resources to locate and enable sustainable and affordable exploration. The criterion for reliable signal detection is that the difference in counts between wet and dry regions must be greater than 3 times the noise. This requirement reflects our assessment of the likely capability of the LRO based on the selected instruments. Based on subjective expert judgment, we believe these requirements will meet or exceed the needs of the broader exploration program once they are explicitly defined.

3.1.2 Project Requirements

NASA has established the following project requirements for LRO which are summarized in this section:

RLEP-LRO-P10 Planetary Protection The LRO will be classified as a Planetary Protection Category I mission.

Rationale : Stringent Planetary Protection of the moon is not required by NASA per NPR 8010.12C, Sec 2.2.1.

RLEP-LRO-P20 Mission Lifetime The LRO mission shall have a minimum 1 year mission lifetime capability with the potential for an extended mission of up to 5 years.

Rationale : The 1 year mission lifetime is based on acquiring the desired measurements globally with varying diurnal and seasonal lighting conditions, improving surface coverage and doing repeat observations to increase sensitivity of key instruments. The extended lifetime objective provides program resiliency and flexibility as required by RLEP-P20 and RLEP-P30.

RLEP-LRO-P30 Launch Date The LRO shall be launched in late 2008.

Rationale : The launch year is per the Nation's Vision for Space Exploration and supports a crewed lunar landing as early as 2018. The information provided by LRO is needed to ensure effective crewed and robotic lander system designs as well as for other future lunar surface system designs.

RLEP-LRO-P40 Launch Site The LRO shall be launched from Cape Canaveral AFS.

RLEP-LRO-P50 Launch Vehicle The LRO shall be launched on a competitively selected Intermediate-class launch vehicle, under the NASA Launch Services contract.

RLEP-LRO-P60 Orbit The LRO shall collect the measurement data, specified in this document, for one Earth year in a 50 km mean (+/- 5km) near-circular polar lunar orbit.

*Rationale***:** The design, performance and resultant data products of the HQ selected instruments are based on this requirement from the AO.

RLEP-LRO-P70 Spacecraft Pointing The LRO spacecraft shall be a 3-axis stabilized nominally nadir-pointing platform.

*Rationale***:** The design, performance and resultant data products of the HQ selected instruments are based on this requirement from the AO.

RLEP-LRO-P80 Spacecraft Instrument Accommodations The LRO shall include an instrument complement consisting of the Lunar Orbiter Laser Altimeter (LOLA), the Lunar Reconnaissance Orbiter Camera (LROC), the Lunar Exploration Neutron Detector (LEND), the Diviner Lunar Radiometer Experiment (DLRE), the Lyman-Alpha Mapping Project (LAMP),

and the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) as selected for measurement investigations.

Rationale: These instruments were competitively selected by NASA HQ on Dec 22, 2004 based on the LRO Measurement Investigations AO, NNH04ZSS003O of June 18, 2004.

RLEP-LRO-P90 Measurement Investigation Requirements The LRO investigation teams shall be responsible for collecting the measurement, engineering, and ancillary information necessary to validate and calibrate the measurement data prior to delivery to the PDS.

RLEP-LRO-P100 Measurement Investigation Requirements Data products delivered to the PDS shall be documented, validated, and calibrated in physical units useable by the exploration and science communities at large.

RLEP-LRO-P110 Measurement Investigation Requirements The time required to complete this process and make the initial data products available via the PDS to the Headquarters and the Program office shall be six months or less from delivery to Earth. New or improved data product releases and derived data products shall be delivered to the PDS as soon as they are available.

RLEP-LRO-P120 Data Policies and Validation Requirements Principal Investigators (PIs) selected for measurement investigations shall plan to archive their Data Products and supporting data in the Planetary Data System (PDS) in a PDS-compliant data format.

RLEP-LRO-P130 Data Policies and Validation Requirements The LRO Project shall develop a Data Management Plan as specified by NPR 7120.5C. The LRO Project shall require the Instrument teams to develop data management plans to meet the subsequent data delivery requirements.

RLEP-LRO-P140 Data Policies and Validation Requirements Initial data analyses for the LRO measurement investigations shall be accomplished by the PIs and their teams.

RLEP-LRO-P150 Communications Compatibility As a goal, the LRO should establish interoperable communications with any contemporaneous Exploration systems and other NASA internal and/or external Lunar missions where it would be advantageous to the exploration effort.

RLEP-LRO-P160 Technology Demonstration The LRO shall accommodate the United States Navy provided Mini-Radio Frequency (RF) instrument in order to provide the opportunity for demonstration of this technology in the lunar orbital environment provided it does not increase the project cost, delay the launch date, adversely impact the achievement of full mission success, or increase the overall risk posture of the primary mission.

Rationale: As directed by the NASA Administrators office.

3.1.3 LRO Requirements Traceability

RLEP Parent Requirement	LRO Child Requirement
RLEP-M10	RLEP-LRO-M10
RLEP-T30 RLEP-M20	RLEP-LRO-M20
RLEP-M30	RLEP-LRO-M30
RLEP-M30	RLEP-LRO-M40
RLEP-M60	RLEP-LRO-M50
RLEP-M40	RLEP-LRO-M60
RLEP-M50	RLEP-LRO-M70
RLEP-M40	RLEP-LRO-M80
RLEP-M40	RLEP-LRO-M90
RLEP-M50 RLEP-M80	RLEP-LRO-M100
RLEP-M50	RLEP-LRO-M110
RLEP-***PTBD***	RLEP-LRO-P10
RLEP-P30 RLEP-P20	RLEP-LRO-P20
RLEP-P10	RLEP-LRO-P30
RLEP-P10	RLEP-LRO-P40
RLEP-P20	RLEP-LRO-P50
RLEP-P10	RLEP-LRO-P60
RLEP-P20	RLEP-LRO-P70
RLEP-P10	RLEP-LRO-P80
RLEP-P40	RLEP-LRO-P90
RLEP-P40	RLEP-LRO-P100
RLEP-P40	RLEP-LRO-P110
RLEP-P40	RLEP-LRO-P120
RLEP-P40	RLEP-LRO-P130

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RLEP Parent Requirement	LRO Child Requirement
RLEP-P40	RLEP-LRO-P140
RLEP-PG30, P20	RLEP-LRO-P150
RLEP-T100	RLEP-LRO-P160

3.1.4 Additional Investigations

NASA may solicit additional participation in the LRO mission (e.g., Interdisciplinary Scientist or Participating Scientist investigations) through future NASA Announcements of Opportunity (AOs) or Research Announcements (NRAs).

4.0 LRO PAYLOAD COMPLEMENT

The LRO will accomplish its measurement objectives (Section 3.0) by conducting a program of global mapping, regional survey, and globally distributed targeted exploration observations for one year or more and by analysis of the returned data. The selected investigations are specified here as follows. In addition, a technology demonstration was added to the payload.

4.1 LUNAR ORBITER LASER ALTIMETER

The Lunar Orbiter Laser Altimeter (LOLA) will determine the global topography of the lunar surface at high resolution, measure landing site slopes, and search for polar ices in shadowed regions.

4.2 LUNAR RECONNAISSANCE ORBITER CAMERA

The Lunar Reconnaissance Orbiter Camera (LROC) will acquire targeted images of the lunar surface capable of resolving small-scale features that could be landing site hazards, as well as wide-angle images at multiple wavelengths of the lunar poles to document changing illumination conditions and globally identify potential resources.

4.3 LUNAR EXPLORATION NEUTRON DETECTOR

The Lunar Exploration Neutron Detector (LEND) will map the flux of neutrons from the lunar surface to search for evidence of water ice, and provide measurements of the space radiation environment, which can be useful for future human exploration.

4.4 DIVINER LUNAR RADIOMETER EXPERIMENT

The Diviner Lunar Radiometer Experiment (DLRE) will map the temperature and broadband solar reflectance of the entire lunar surface over a full diurnal cycle to define the thermal environments of potential landing sites, identify potential landing hazards, identify potential cold-traps, and map variations in silicate mineralogy.

4.5 LYMAN-ALPHA MAPPING PROJECT

The Lyman-Alpha Mapping Project (LAMP) will observe virtually the entire lunar surface in the far ultraviolet. LAMP will search for surface ices and frosts in the polar regions and provide frost abundance, landform and surface UV spectral maps of permanently shadowed regions illuminated only by starlight and interplanetary Lyman alpha.

4.6 COSMIC RAY TELESCOPE FOR THE EFFECTS OF RADIATION

The Cosmic Ray Telescope for the Effects of Radiation (CRaTER) will investigate the effect of cosmic rays on tissue-equivalent plastics as a constraint on models of biological response to background space radiation.

4.7 MINI-RF TECHNOLOGY DEMONSTRATION

The primary purpose of the Mini-RF payload is technical demonstration of a unique miniaturized multi-mode dual frequency (X&S band), dual polarization radar observatory. The primary image data products will be multi-mode Stokes parameters (or their primitives), a major pioneering capability in space-based radar astronomy. Additional communications and navigation demonstrations will also be made to validate new instrument technologies.

5.0 LRO MISSION SUCCESS CRITERIA

It is NASA's intent that LRO meet the Full Mission Success Criteria, however, in the event of a problem with the LRO mission/spacecraft, the Minimum Mission Success criteria should then be used to prioritize observations to enable the targeting and safe landing of subsequent surface lander mission(s). Based on sections 3.1.1, Measurement Requirements and 3.1.2, Project Requirements herein, the following mission success criteria have been established for the LRO Project.

5.1 FULL MISSION SUCCESS CRITERIA

For Full Mission Success, the following criterion must be met:

- Meet all the requirements (M10-P160) set forth in this document, including operating the LRO in the primary lunar mapping orbit for at least one year and delivering the specified data products in Table 6-1 to the Program Office via the PDS within six months of acquisition.

5.2 MINIMUM MISSION SUCCESS CRITERIA

For Minimum Mission Success, the following criteria must be met and shall be used in a contingency situation to prioritize observations in the North and South polar regions redefined as 88.5°+. It shall also be used for development descope planning and execution. The requirements M10-P160 are revised as follows:

Landing Site Characterization (to enable landing site safety analyses)

1. Obtain geodetic lunar polar region topography with spatial resolution of 50m (horiz), 2m (vertical) to an accuracy of 500m horizontally and 18m vertically (to enable slope, small crater location, crater size and distribution determination)

2. Assess meter-scale features of the lunar surface (including rock size and abundance) in the polar regions.

3. Characterize the Moon's polar region illumination environment to identify permanently shadowed regions (for potential water-ice locations) and permanently illuminated sites.

Data Archival

4. Archival of the acquired data sets in the Planetary Data System in a timely manner, not to exceed 12 months after data acquisition.

6.0 MEASUREMENT DATA

6.1 MEASUREMENT DATA MANAGEMENT

Each PI led instrument team on the LRO mission is responsible for initial analysis of the measurement investigation data, the subsequent delivery of the data products and software to the Planetary Data System (PDS), publication of findings and communication of results to the public.

It is NASA policy that investigators do not have exclusive use of data taken during the course of their investigation for any proprietary period. After a short period for verification and validation, not to exceed six months after the measurement data and ancillary information are first available to the investigation team, each Principal Investigator (PI) must deposit the initial validated data in the PDS in a compliant data format. Analysis, preparation, distribution and archiving of all subsequent investigation team data products are to be completed within six months of the end of the prime mission phase during which the investigation measurement data were acquired. Improved or derived data products shall be archived in the PDS as soon as they are available, on a time scale commensurate with the level of data processing required.

6.2 MEASUREMENT DATA PRODUCTS

The following table 6-1 describes the associated data product each instrument will produce in response to the LRO measurement requirements.

Table 6-1 LRO Data Products.

LRO Measurement Objective	LRO Instrument	Data Product
RLEP-LRO-M10	LEND	Radiation Data Product for global distribution of neutrons at Moon's orbit with spatial resolution of 50 km at different energy ranges from thermal energy up to >15 MeV separately for periods of quiet Sun and for periods of Solar Particle Events.
	CRaTER	Provide Linear Energy Transfer (LET) spectra of cosmic rays (particularly above 10 MeV), most critically important to the engineering and modeling communities to assure safe, long-term, human presence in space.
RLEP-LRO-M20	CRaTER	Provide LET spectra behind different amounts and types of areal density, including tissue-equivalent plastic.
RLEP-LRO-M30	LOLA	Provide a global digital elevation model of the Moon with 10cm vertical resolution, 1m vertical accuracy and 50-100m horizontal resolution with 1 km average cross track sampling at the equator.
RLEP-LRO-M40	LOLA	Provide global topography of the Moon with 10cm vertical resolution, 1m vertical accuracy and 50-100m horizontal resolution with 1 km average cross track sampling at the equator.
	LROC	For areas of high interest (targets), collect multi-look NAC data reducible to 2m scale Digital Elevation Models (DEM) for 25 km^2 areas.
	LROC	Acquire 100 m/pixel global stereo imaging reducible to 1km/pixel global topography in EDR format (no maps). Note: This is an unprocessed backup product for LOLA.

RLEP-LRO-M50	Diviner	Temperature maps at better than 500m spatial resolution from 40-300K over an entire diurnal cycle to enable the detection and characterization of cold traps in polar shadowed regions.
RLEP-LRO-M60	LOLA	Provide global topography with 10cm vertical resolution, 1m vertical accuracy and 50-100m horizontal resolution with 1 km average cross track sampling at the equator.
	LAMP	Albedo maps of all permanently shadowed regions with resolutions down to 100m.
RLEP-LRO-M70	LOLA	Provide Reflectance data from the permanently shadowed regions to identify surface ice signatures at a limit of 4% ice surface coverage by area.
	LEND	Develop maps of putative water-ice column density on polar regions of the moon with spatial resolution of 10km.
	LAMP	Develop water-frost concentration maps of the lunar polar regions. Mapping resolutions as good as 3km for frost abundances down to 1.5%.
RLEP-LRO-M80	LROC	Provide up to 50 Mosaics of selected potential landing sites with one meter scale resolution.
	LROC	Provide crater size density and size distribution maps of up to 10 potential landing sites (100 km^2/site).
	Diviner	Provide rock (>=0.5m dia) abundance percentages for up to 50 selected potential landing sites by measuring the ratio of high thermal to low thermal inertia material.
	LOLA	Provide topography, surface slopes, and surface roughness at 25-m spacing over a 70m wide field of view (FOV) swath at up to 50 selected potential landing sites.
RLEP-LRO-M90	LROC	Provide uncontrolled illumination movies, 1 each of North and South Lunar Poles over the course of 1 lunar year at an average time resolution of 5 hours or better. (Wide Angle Camera [WAC])
	LROC	Provide meter scale resolution summer (uncontrolled) mosaics of the lunar poles (+/- 4 degrees). (Narrow Angle Camera [NAC]). Some gores in the data beyond the polar regions are acceptable.
	LOLA	Polar region maps of latitudes 86°-90° with a vertical resolution of 10 cm and a spatial resolution of 25 to 35m after one year. This will help to identify potential sites of optimal solar power generation.
	Diviner	Provide polar illumination map at better than 500m spatial scales over a full diurnal cycle.
RLEP-LRO-M100	LROC	Global imaging 400m/pixel in the ultraviolet (UV) bands and 100m/pixel in the visible bands, ten uncontrolled demonstration multi-spectral mosaics for high priority targets.
	Diviner	Global fine-component thermal inertia, silicate mineralogy and Lambert albedo from thermal emission, solar reflectance and topography measurements with greater than 50% spatial coverage at the equator.
RLEP-LRO-M110	LEND	Determine hydrogen content of the subsurface at the polar regions with spatial resolution of 10km and with sensitivity to concentration variations of 100 parts per million (ppm) at the poles.

Because of their exceptional value for public engagement, representative images and data products will be made available publicly throughout the mission, shortly after reception on the ground. Release of LRO data by the LRO measurement investigation teams and team leads, and by the LRO Project shall comply with the policies for release of data and public information and shall be coordinated through the RLEP Program Office and the ESMD Communications Office (due to the visibility of this mission). In addition, NASA reserves the right to direct the acquisition of data, to direct or conduct data processing, and to release data needed for mission operations, programmatic planning, and support of public engagement. The number and extent of such directives will be consistent with other LRO mission objectives and with Project resources.

7.0 EXTERNAL AGREEMENTS

NASA requires an LOA, MOU, or IA between NASA and each of the foreign agencies for delivery of hardware, software products, or services. The Program Executive working with External Relations Office will facilitate. In order to establish a working environment conducive to free and open exchange of information between LRO and the foreign partners, Technnology Transfer Agreements (TTAs), Implementing Agreement (IA) or a Memorandum of Understanding (MOU) will be established with each participating member. The foreign partners identified to participate in LRO include:

Russian Federal Space Agency (Roskosmos)

NASA will also develop an agreement to define the relationship between LRO and the Mini-RF technology demonstration.

8.0 EDUCATION AND PUBLIC OUTREACH

The public outreach component of the LRO project shall be implemented as part of a unified program level Education and Public Outreach activity organized, managed and funded by the Robotic Lunar Exploration Program with funds allocated for this purpose. In addition, Principal Investigators of instruments selected through the AO shall conduct local EPO activities that will be coordinated with the RLEP EPO activities.

9.0 TAILORING

The LRO mission shall be conducted in a manner compliant with NPR 7120.5C.

APPENDIX A: ACRONYMS

AA Associate Administrator
AFS Air Force Station
AO Announcement of Opportunity
CEV Crew Exploration Vehicle
CG Center of Gravity
CLV Crew Launch Vehicle
CRaTER Cosmic Ray Telescope for the Effects of Radiation
DEM Digital Elevation Model
DLRE Diviner Lunar Radiometer Experiment
DSN Deep Space Network
EDR Experimental Data Record
EPO Education and Public Outreach
ESMD Exploration Systems Mission Directorate
FBO Federal Business Opportunity
FOM Figures-of-Merit
FOV Field of View
GCR Galactic Cosmic Ray
GSFC Goddard Space Flight Center
GN&C Guidance, Navigation, and Control
HR&T Human & Robotic Technology
HWHM Half Width and Have Maximum (of the instrument field of view)
HQ Headquarters (NASA)
IA International Agreement
IPAO Independent Projects Assessment Office
ISRU In-Situ Resource Utilization
ITA Independent Technical Authority
K Kelvin
km Kilometers
KSC Kennedy Space Center
LAMP Lyman-Alpha Mapping Project
LEND Lunar Exploration Neutron Detector
LEO Low Earth Orbit
LET Linear Energy Transfer
LLO Low Lunar Orbit
LOA Letter of Agreement
LOLA Lunar Orbiter Laser Altimeter
LRO Lunar Robotic Orbiter
LROC Lunar Robotic Orbiter Camera
m Meters
M Meters
MeV Mega-electron Volts
mm Millimeters

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MOU Memorandum of Understanding
NAC Narrow Angle Camera
NAR Non-Advocate Review
NODIS NASA Online Directives Information System
NP NASA Publication
NPD NASA Policy Documents
NPR NASA Procedural Requirement (Document)
NPSD National Security Presidential Directive
NRA NASA Research Announcements
OD Orbit Determination
ORDT Objectives and Requirements Definition Team
OSMA Office of Safety and Mission Assurance
PDR Preliminary Design Review
PDS Planetary Data System
PI Principal Investigator
PIP Proposal Information Package
PMC Program Management Council
ppm Parts Per Million
PRA Probabilistic Risk Assessment
PSR Permanently Shadowed Regions
RFP Request for Proposals
RLEP Robotic Lunar Exploration Program
RPS Robotic Precursor System
SMD Science Mission Directorate
SNR Signal-to-Noise Ratio
SPE Solar Particle Event
SRR System Requirements Review
STD Standard (Document)
TBD To Be Determined
TBR To Be Resolved
TRL Technology Readiness Level
TTA Technology Transfer Agreements
WAC Wide Angle Camera
UV Ultraviolet

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